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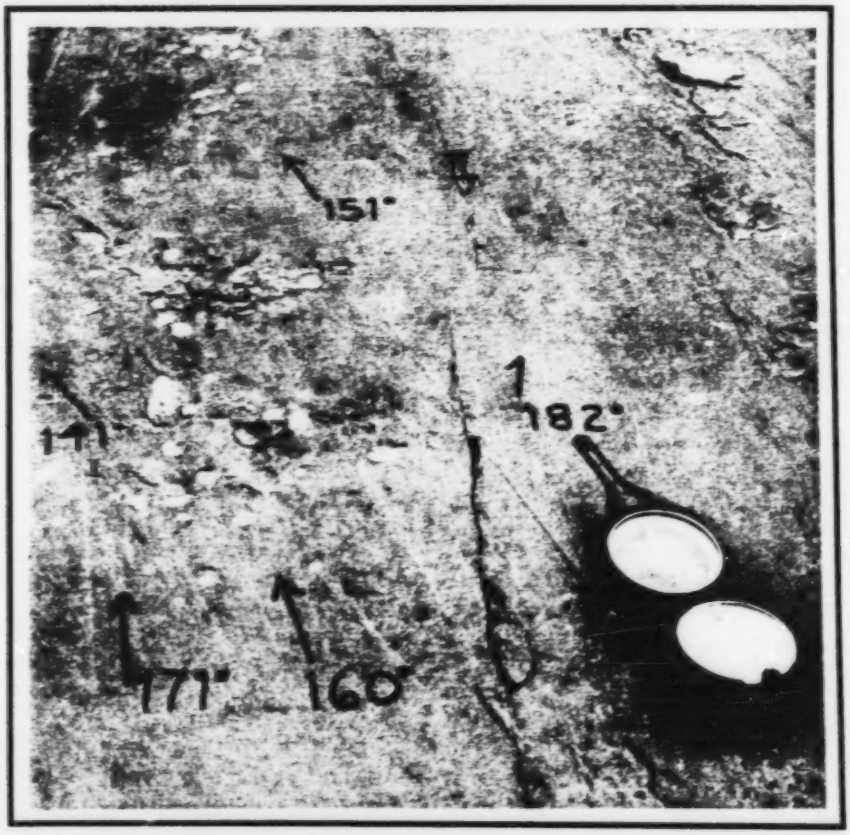
Geoscience Report 89-2

Complex Glacial Ice-Flow Events in New Brunswick with Particular Reference to the Oromocto Lake Area, and Implications for Drift Prospecting

A.A. Seaman



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Cover Photo:
Five striae sets on part of a pebbly sandstone outcrop near Prince William, York County. Elsewhere on this outcrop, a few striae of two additional sets (130° and 189°) are present.

This report has been prepared by:

Mineral Resources
Department of Natural Resources and Energy
Province of New Brunswick

Hon. Morris Green
Minister of Natural Resources and Energy

Hon. Edmond P. Blanchard
Minister of State for Mines

March, 1991

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Brunswick

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COMPLEX GLACIAL ICE-FLOW EVENTS IN NEW BRUNSWICK WITH PARTICULAR REFERENCE TO THE OROMOCTO LAKE AREA, AND IMPLICATIONS FOR DRIFT PROSPECTING

ABSTRACT

Past studies of glacial events in New Brunswick have revealed complex regional striae patterns, including several areas where the ice-flow direction has been completely reversed. To the mineral explorationist engaged in drift prospecting, this raises the problem of identifying which ice-flow direction corresponds to the glacial deposits that are being sampled.

Traditionally, it has been assumed that glacial transport was in the direction of the locally dominant striae pattern. However, in the Oromocto Lake area of southwestern New Brunswick this has been found to be an untrue assumption. The dominant striae trends are southerly to southeasterly, but lesser trends cover the entire range from east-northeasterly clockwise to westerly. In addition, till pebble lithologies reveal that, at least locally, the direction of till transport was toward the north to northwest. Thus, there were also reversals in ice-flow direction in the Oromocto Lake area. By implication, similar flow reversals, as of yet unidentified, may have occurred in other parts of New Brunswick.

The implications of the discovery of northerly to northwesterly till transport in the Oromocto Lake area are significant to the mineral explorationist. It is an obvious waste of exploration dollars and effort to seek a hidden orebody to the northwest of a drift geochemical anomaly if the material was derived from an area to the south. At the present time, it is recommended that till pebble lithological characteristics, rather than glacial erosion marks, be used as the guide to determining the direction of till transport.

RÉSUMÉ

Des études antérieures des processus glaciaires du Nouveau-Brunswick ont révélé des réseaux régionaux complexes de stries glaciaires, y compris plusieurs cas où la direction de l'écoulement glaciaire a été complètement inversée. Pour le prospecteur minier qui effectue de la prospection à partir de telles données, cette situation soulève le problème de cerner à quel écoulement glaciaire correspondent les débris prélevés comme échantillons.

Traditionnellement, on a toujours pensé que l'écoulement glaciaire se déterminait selon le sens du réseau de stries locales dominant. Dans la région du Lac Oromocto, situé au sud-ouest du Nouveau-Brunswick, cependant, on s'est aperçu que cette supposition était complètement fausse. En effet, dans

cette région, le réseau de stries dominant s'étend en direction sud à sud-est. Cependant, des réseaux secondaires sillonnent l'ensemble de la région en direction est-nord-est à ouest, et ce, dans le sens des aiguilles d'une montre. En outre, les études pétrographiques des débris rocheux de tills révèlent que, du moins de manière locale, l'écoulement glaciaire s'est effectué en direction nord à nord-ouest. Ainsi, on se rend compte qu'il y a eu inversion complète de la direction de l'écoulement glaciaire dans la région du Lac Oromocto. Implicitement, il est possible que d'autres inversions de l'écoulement glaciaire, pour l'instant non identifiées, se soient produites dans d'autres parties du Nouveau-Brunswick.

Les implications suggérées par la découverte de cette inversion de l'écoulement glaciaire dans la région du Lac Oromocto sont très significatives pour le prospecteur minier. Il est évident que rechercher un gisement au nord-ouest d'une anomalie géochimique d'écoulement glaciaire alors que les matériaux transportés proviennent d'une région plus au sud constitue un gaspillage des fonds alloués aux activités de prospection. Donc, pour le moment, on recommande d'utiliser les caractéristiques des débris rocheux relevées dans le cadre d'études pétrographiques plutôt que les marques d'érosion glaciaires afin de déterminer la direction de ces mêmes mouvements glaciaires.

INTRODUCTION

Examination of the glacial striae data collected in New Brunswick over the past century and a half (summarized in Seaman 1989a) reveals that the Province is characterized by a multitude of glacial flow directions. These multiple flow directions were first recognized by Robert Chalmers of the Geological Survey of Canada during his mapping of the surficial geology of the Province in the latter part of the 19th Century (Chalmers 1881, 1882, 1884, 1885, 1887, 1888, 1890a, 1895, 1902). Chalmers attributed the diversity of flow directions to interaction between a number of local ice caps, which he referred to as "the Appalachian system of glaciers" (Chalmers 1890b, 1898).

Subsequent workers in adjacent areas largely ignored or discredited Chalmers' observations, since his data did not accord with the popular conceptual model of glaciation by a continental ice sheet flowing southward from northern Canada (e.g., Goldthwait 1924). However, recent work in New Brunswick (Gauthier 1978, 1979, 1980, 1982, 1983; Gauthier and Cormier 1977; Pronk et al. 1989; Rampton and Paradis 1981a, 1981b, 1981c; Rampton et al. 1984; Rappol 1986, 1988, 1989) and Nova Scotia (Grant 1977; Stea et al. 1986) has confirmed Chalmers' observations and revived his concept of glaciation by interacting local ice caps.

A summary of glacial striae orientations in New Brunswick was presented by Rampton et al. (1984). This summary identified the major ice-flow directions and grouped them into flow patterns. Each flow pattern was assigned an approximate geographic extent and chronological age. However, new striae data collected since 1984 has revealed a more complicated situation with regard to ice-flow events than was

apparent from the data available to Rampton et al. (1984). Individual ice-flow patterns appear to be more extensive than previously recognized and, in addition, there appear to have been many more ice-flow events.

Another discovery of significance is the fact that the statistically calculated trend of elongate pebbles in the tills (till fabric) is often at variance with the major striae directions on underlying or adjacent bedrock surfaces. This implies that till transport may not be closely tied to the major striae pattern within an area, an interpretation supported by the examination of till pebble lithologies at several sites. This is of particular importance to mineral explorationists attempting to identify the bedrock source areas for geochemically anomalous overburden samples.

The purpose of this report is to document the variety of glacial flow directions in New Brunswick, based on all available striae data. In addition, the degree of complexity possible will be highlighted by reference to the results of recent investigations in the Oromocto Lake area of southwestern New Brunswick. Finally, the implications of this complexity as they pertain to mineral exploration will be discussed.

ICE-FLOW DIRECTIONS

BACKGROUND

All of the known glacial striae trends measured in New Brunswick, up to 1988, have been compiled by Seaman (1989a). That report should be referred to for a detailed listing of the data that is cross-referenced to the original sources, and for a full listing of these source references. This striae trend data has been further synthesized for presentation on the map that accompanies this report (Plate 89-11).

Typically, map compilations of striae consist of plots of striae orientations at representative sites, indicated by means of a symbol (for example, Rampton et al. 1984; Thompson and Borns 1985). However, two potentially undesirable characteristics of such compilations have since become apparent.

First, if a large amount of striae orientation data exists for one particular area, some, or much, of it may have to be edited out. For example, on their 1:500 000 scale striation summary map Rampton et al. (1984) plot 19 striae orientations for the approximately 1000 km^2 of the Burtts Corner (NTS 21 J/2) map area. This compares to the total of 107 striae orientations reported by Anderson and Poole (1959), Chalmers (1884, 1885, 1902), Poole (1957), Rampton and Paradis (1981a), and Seaman (1981). While several of the striae sites may be common to two or more of the above authors, there has still been a significant reduction in the amount of information presented. This is a particular problem if striae trends that only occur rarely are deleted. For example, for the Burtts Corner map area Chalmers (1902) reports a few sites with southwest-trending striae, but none of these were plotted by Rampton et al. (1984). However, they may correlate with the flow pattern of similar trend that is plotted by Rampton et al. (1984) for the Minto (21 J/1) map area, immediately to the east. Thus, this southwest-trending ice-flow event may be of greater extent than is apparent from the Rampton et al. (1984) compilation.

Second, it is difficult to assess such maps visually in terms of ice-flow variation and extent, since a few striae symbols for a minor ice-flow pattern can become lost among the many symbols for a dominant flow pattern.

Recent work in southwestern New

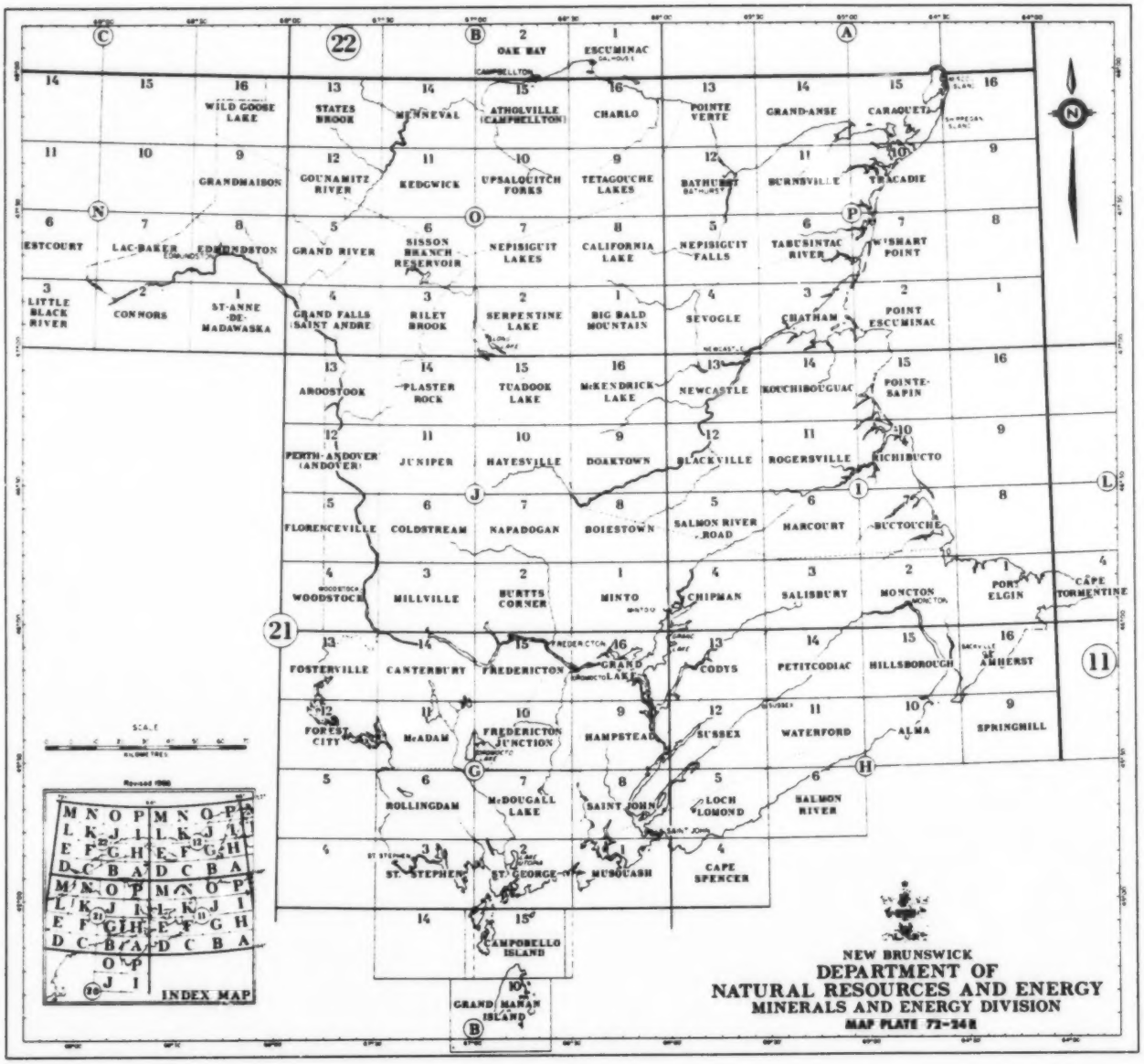


Figure 1. 1:50 000 scale NTS map areas in New Brunswick.

Brunswick has revealed that such characteristics are undesirable for two significant reasons. First, the numerically dominant and strongest striae pattern in one area may occur in an adjacent area at only a few scattered sites. If the data on these minor striae occurrences is edited out or is not readily evident, the true extent of the ice-flow pattern is not recognized, as is the case with the southwest-trending ice flow in the Burtts Corner area. Second, and of particular significance to mineral explorationists, the formation of the surface till sheet is expected to have been the result of the latest glacial event in an area, and thus is not necessarily related to the major erosive ice-flow patterns that are typically early glacial events in southwestern New Brunswick.

In order to accurately determine the extent of given erosive ice-flow events in an area, one requires an extensive body of striae orientation data. The determination of the chronology of the various erosive ice-flow events requires data that clearly show the cross-cutting relationships between the striae associated with the different events. Correlation of these events with glacial deposits requires thick till sections exposing multiple stratigraphic units. Unfortunately, none of these criteria can be met in New Brunswick at the present time. While some areas have extensive data sets consisting of hundreds of striae orientation measurements, other areas have only a few measurements, or none at all. Data on cross-cutting relationships is very sparse, and sometimes contradictory. As well, the virtually ubiquitous thin (1 to 2 m thick) till sheet overlying bedrock appears to consist of a single stratigraphic unit, and thus provides no stratigraphic control to aid in chronological interpretations.

Consequently, an alternate method of ice-flow direction synthesis and presentation was developed that would present all known ice-flow directions in New Brunswick on an equal-weight basis. This method permits the identification of possible regional trends, and also identifies the degree of complexity that is known in a specific area. However, as noted above, it is not yet possible to outline the chronological sequence of glacial events at the provincial scale.

The methodology used in this synthesis is outlined below.

DATA SYNTHESIS AND PRESENTATION

The key to this method of data synthesis is to treat every known ice-flow direction within a specific unit area as a single data point, irrespective of the number of times that it recurs within the area. For the purposes of a regional study such as this, the existing National Topographic System (NTS) 1:50 000 scale map areas provide the most convenient subdivision of the province into unit areas. Ninety-three such map areas, or parts thereof, lie within the Province of New Brunswick (Figure 1). Each map area lying totally within the province comprises an area of just over 1000 km^2. Since most of the ice-flow patterns identified by Rampton et al. (1984) are relatively straight-line flows covering areas of several thousand square kilometres, the loss of precision inherent in this synthesis should not be significant in a regional context.

The striae trend data compiled by Seaman (1989a) was compiled on the basis of the NTS map areas. The data for each map area was then synthesized into sectors of the compass toward which the ice is known to have flowed (either within that map area, or in an immediately adjacent

Figure 2. Location of the Oromocto Lake study area

map area), and into sectors toward which the ice may possibly have flowed. The resulting sectors, for each map area, are plotted on Plate 89-11. The intricacies of the data synthesis process are discussed in detail in Appendix A.

DISCUSSION

The results of this exercise, as plotted on Plate 89-11, indicate that New Brunswick has been subject to ice-flow from many different directions. Several broad regional patterns are evident. In the northwestern, northeastern and southeastern parts of the Province very complex patterns exist, including complete reversals in the ice-flow trends. In the southwest, ice- flow trends appear to have varied from northeastward through southeastward to southwestward, while in the central part of the Province, they vary from northward through eastward to southward.

The map may also be used to infer the extent of ice-flow events. For example, a few scattered northeast-trending striae in southwestern New Brunswick appear to define a previously unrecognized flow pattern that is of regional extent. There is some suggestion that it may be coincident with the Kent, Harcourt or Doaktown flow patterns in eastern New Brunswick that were identified by Rampton et al (1984). If this is the case, there may have been a continuous ice sheet that flowed from southern Maine across southwestern New Brunswick and on to Northumberland Strait. If so, this could have a significant bearing on till transportation and deposition in the southern part of the Province. Obviously, this is a theory worthy of future investigation, as are other apparent relationships between ice-flow trends in different parts of the Province. For example, is the eastward ice-flow event in northern New Brunswick the same event as the one in the south? Are the northwestward ice-flow events in the northeast and the southeast the same event? Is the evidence for southeastward ice flow that occurs almost ubiquitously across the province due to one single phase of glaciation, or to several that followed a similar course? Did the ice-flow patterns follow straight-line paths, or did they follow curved trajectories? Are the multitude of ice-flow trends that are apparent the result of interaction between local ice-caps as suggested by Rampton et al. (1984) and others, or are they due to inundation of the Province by extensive, province-wide ice sheets that flowed into New Brunswick from different source areas at different times? Are there characteristics of the tills that permit them to be correlated with specific ice-flow events? Answering these questions and others like them will increase our knowledge of the glacial processes and events that shaped New Brunswick, and also improve our ability to use glacial deposits in the search for economically viable ore bodies.

In an effort to begin to answer some of these questions, a preliminary study of the correlation between striae trend data and till characteristics was carried out in the Oromocto Lake area of southwestern New Brunswick.

ICE-FLOW EVENTS IN THE OROMOCTO LAKE AREA

BACKGROUND

The Oromocto Lake area lies in southern York County and southwestern Sunbury County, in southwestern New Brunswick (Figure 2). It comprises parts of NTS 1:50 000 scale map areas 21 G/10 (Fredericton

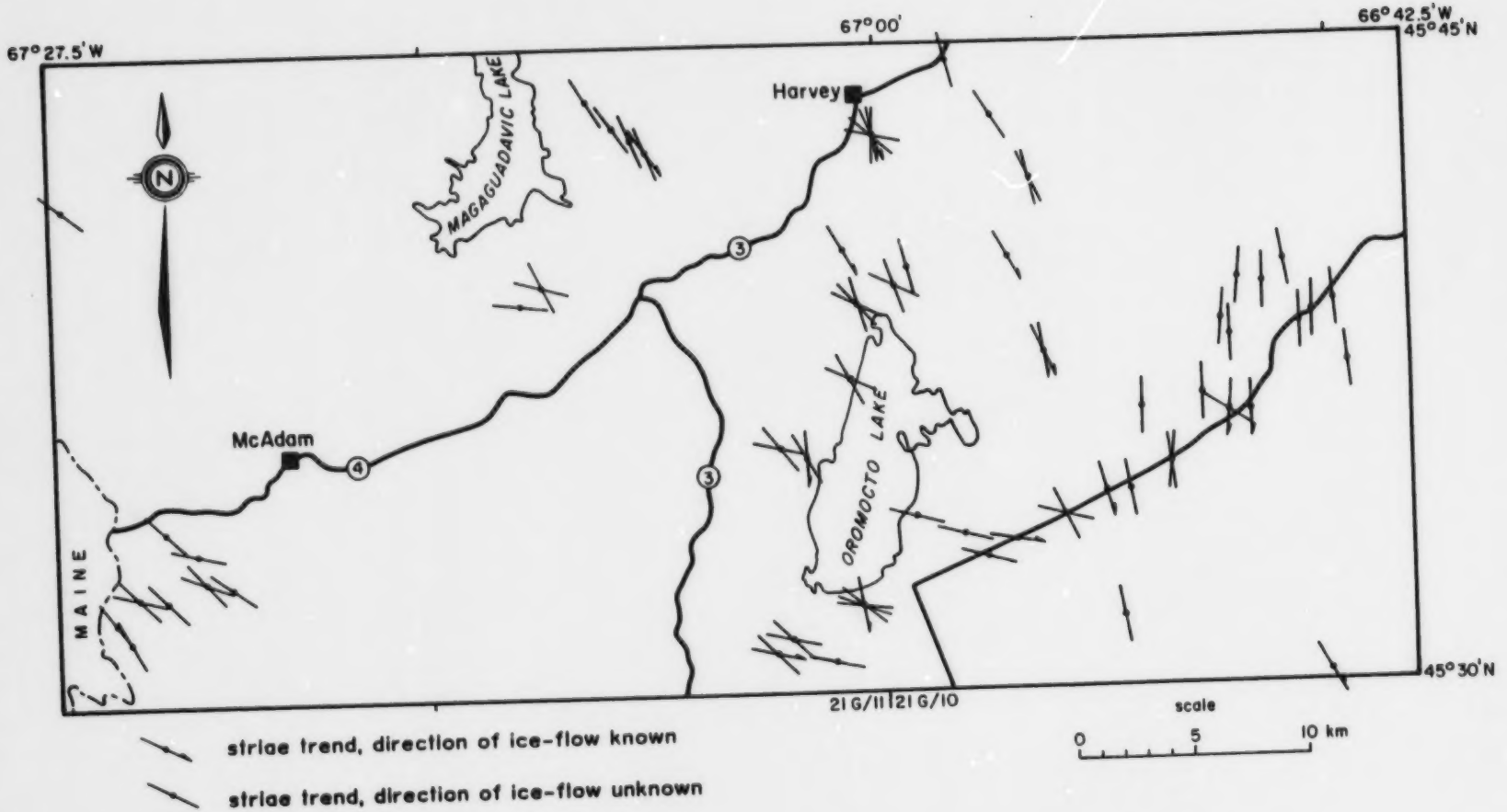


Figure 3. Striae data for the Oromocto Lake area, pre-1984 (summarized from Clark 1961, 1962; Gadd 1973; Seaman 1982; Thibault 1981, 1984).

Junction) and 21 G/11 (McAdam). Striae data previously collected by Clark (1961), Gadd (1973), and Seaman (1982) indicate that the major ice-flow direction for the area west of Oromocto Lake was southeastward (Figure 3). Similar data collected by Clark (1962), Gadd (1973), and Thibault (1981, 1984) indicate that the major ice-flow direction for the area to the east of Oromocto Lake was southward (Figure 3). This discrepancy between the major ice-flow directions to either side of Oromocto Lake was recognized by Gadd (1973), who suggested that the lake marked the approximate boundary between two separate ice lobes at a late stage in glaciation, an interpretation previously supported by the author (Seaman 1982).

Rampton et al. (1984) identified five major ice-flow patterns that affected southwestern New Brunswick (the area to the south and west of the Saint John River), all of which were known to occur in the Oromocto Lake area. The first of these was an eastward-trending ice-flow event that was assigned a pre-Late Wisconsinan age. The remaining four events were assigned to the last glacial interval, the Late Wisconsinan. These were: the southeast-trending Tay and St. Stephen flow patterns, to the east and west, respectively, of Oromocto Lake; the south-trending Oromocto flow pattern to the east of Oromocto Lake; and a local eastward-trending flow pattern attributed to the Passamaquoddy diversion, at the south end of the lake (Rampton et al. 1984, their Figure 27).

Rampton et al. (1984) indicate that the Tay flow pattern, derived from an ice centre over northern Maine and the Notre Dame Mountains of Quebec (the North Maine-Notre Dame Ice Divide complex), was the earliest of these Late Wisconsinan events. Ice of this flow pattern was interpreted as interacting with southward-flowing ice from the Gaspereau Ice Centre, situated over central New Brunswick. Eventually, the Gaspereau ice appeared to have overpowered the ice of the Tay flow pattern in the area to the east of Oromocto Lake, replacing it with the Oromocto flow pattern (Rampton et al. 1984). However, southeastward flow (the St. Stephen flow pattern) was interpreted as continuing in the area to the west of the lake, resulting in the presence of two coexisting ice lobes, as originally suggested by Gadd (1973). Subsequent retreat of the ice from the Bay of Fundy coast was accompanied locally by a late eastward-trending ice flow event, the Passamaquoddy diversion (Rampton et al. 1984).

The above model for the Late Wisconsinan glacial sequence in southwestern New Brunswick was reasonable in terms of its agreement with the body of data that was available to Rampton et al. (1984) at that time. However, new data collected from southwestern New Brunswick during the summers of 1988 and 1989 has revealed a significantly more complex situation. There appear to be at least 16 separate ice-flow events evident from the striae record (Seaman 1989c), including a major, late, eastward-trending flow event (Seaman 1989b). Two factors further contribute to this complexity. First, a major erosive ice-flow event (i.e., the one recorded by the most abundant and heaviest striae) in an area may decrease in magnitude to become a minor event in an adjacent area, or even on an adjacent outcrop. Second, the ice-flow events recorded by the striae may have little or no correlation to the direction of ice flow during till transport and deposition.

ICE-FLOW INDICATORS

Striae Data Detailed examination of striated outcrops in the

Oromocto Lake area has revealed that a multitude of ice-flow events have occurred throughout the area. Typically, three to ten different striae sets are recorded on a single outcrop surface (Figure 4). Each set is presumed to relate to one ice-flow event, as in a set with a range from 158° to 165°, with an average trend of 161°. Table I lists the observed striae from one such site.

Twenty-four outcrop surfaces have been examined in the area to the west of Oromocto Lake, and a further 42 in the area to the east of the lake. The data from these sites is summarized on Figure 5. Figure 6 compares the new striae trend data from sites to the east of the lake with the data from sites to the west of the lake by plotting the number of outcrops at which striae trending at each specific one degree interval have been observed (i.e., for the striae set ranging from 181° to 185° at Site 89-24, one entry is recorded under each of 181, 182, 183, 184 and 185° on the histogram for the area to the west of the lake). The ice-flow direction was determined from features such as rat-tails (Figure 7a), wedge striae (Figure 7b), nail-head striae (Figure 7c), and reverse crescentic scars (Figure 7d). [See Prest (1983) for further illustrations and discussion of these features.]

Figures 5 and 6 clearly reveal that, while evidence for southeastward flow is more abundant to the

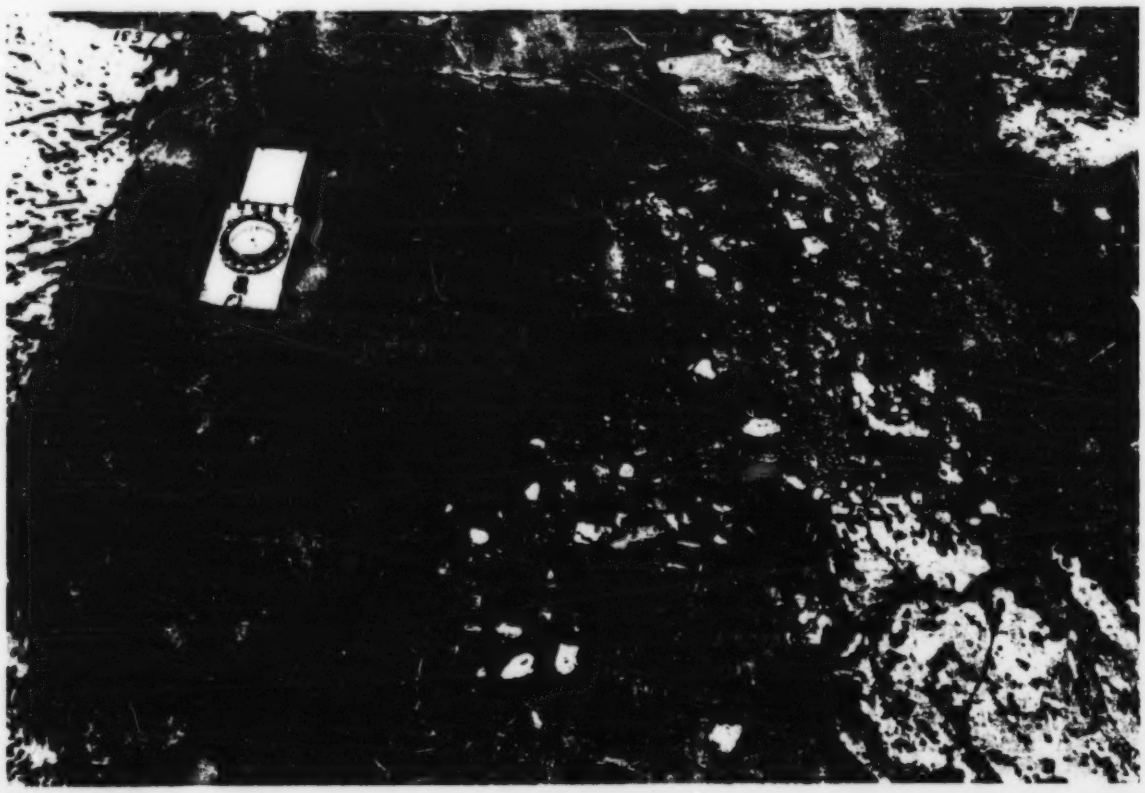


Figure 4. A typical multiply striated bedrock surface south of Harvey. The three major striae sets are marked on the outcrop surface (110, 150, and 168°). A striae of the minor 140° set is evident to the right of the hinge of the compass. Elsewhere on this surface, striae sets with average orientations of 090, 124, 132, and 183° have been observed.

TABLE I. STRIAE TRENDS, SITE 89-24 (GREYWACKE)

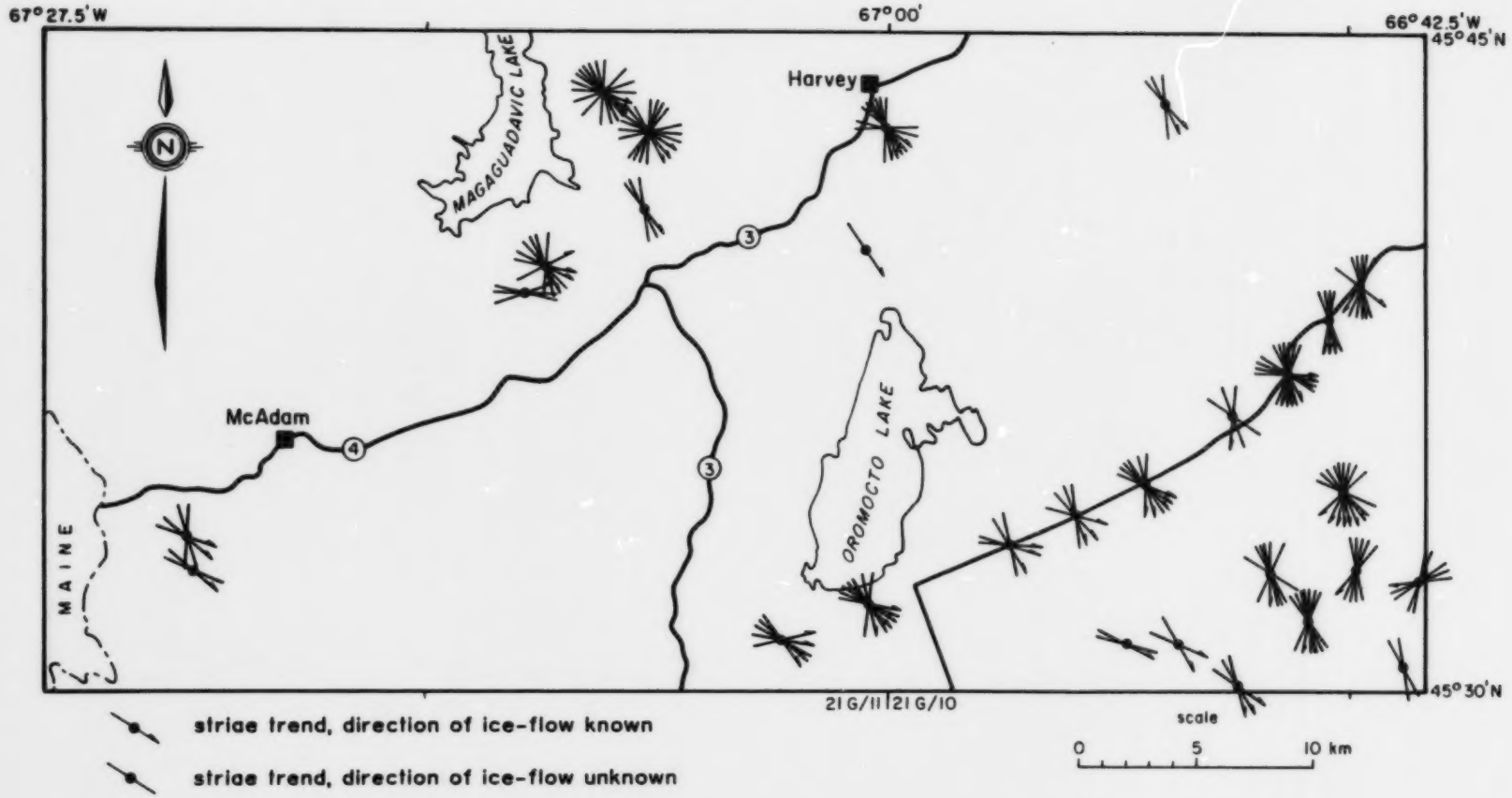
070-072° (avg 071°)	- a few, generally very fine striae
090-095° (avg 092°)	- a few, generally very fine striae
110°	- a few striae; flow direction confirmed by a wedge striae
118-125° (avg 122°)	- a few striae, some relatively large
130-134° (avg 132°)	- a minor flow event; flow direction confirmed by wedge striae
139-147° (avg 143°)	- dominant flow event; flow direction confirmed by wedge striae, and crag and tail features in the lee of quartz veins
167-170° (avg 168°)	- a few striae
181-185° (avg 183°)	- a few generally very fine striae
222-227° (avg 225°)	- a few striae

west of Oromocto Lake and evidence for southward flow is more abundant to the east of the lake, essentially the same flow directions occur in both areas. In addition, the histograms of Figure 6 do not exhibit relatively smooth curves, but rather a series of peaks. Each major peak, and many of the minor ones, appears to be a separate ice-flow event. They correlate well with the average trends of the striae sets as determined in the field. There is also reasonably good correlation between the major peaks in the two histograms. This suggests that the same events occurred on both sides of the lake. These peaks also correlate well with the peak ice-flow directions identified in a preliminary analysis of striae data for all of southwestern New Brunswick (Seaman 1989c), suggesting that these flow events were of regional extent.

The apparent correlation between the events on either side of Oromocto Lake is further supported by the limited amount of chronological data collected from the area. While some cross-cutting relationships have been observed only on one side of the lake or the other, those that have been observed on both sides consistently occur in the same chronological order (Table II).

All 16 of the regional ice-flow events identified by Seaman (1989c) are recorded in the striae data summarized in Figure 6. No evidence was observed that would suggest that there was an interval of deglaciation between any of the striae sets. Consequently, all of these ice-flow events are assumed to have occurred during a single episode of glaciation. In addition, no evidence for the early, eastward-trending ice-flow event identified by Rampton et al. (1984) was observed. However, there is no valid reason to discount the existence of such an event, at least as of yet. Evidence for such an old event would be expected to be preserved but rarely; also, it may be difficult to differentiate from the late eastward flow event at the sites that were examined.

Till Fabric Data In most cases, the statistically dominant orientation trend of elongated clasts in a till (the "till fabric") is interpreted as lying parallel to the direction of ice flow at the time of deposition (Harris 1972), though under some circumstances fabrics oriented transverse to the flow direction are possible (Harris 1972; Flint 1971). While not conclusive, the imbrication of the clasts in the



N.B. - In some cases, it has been necessary to combine data from several adjacent sites

Figure 5. Striae data collected from the Oromocto Lake area in 1988 and 1989.

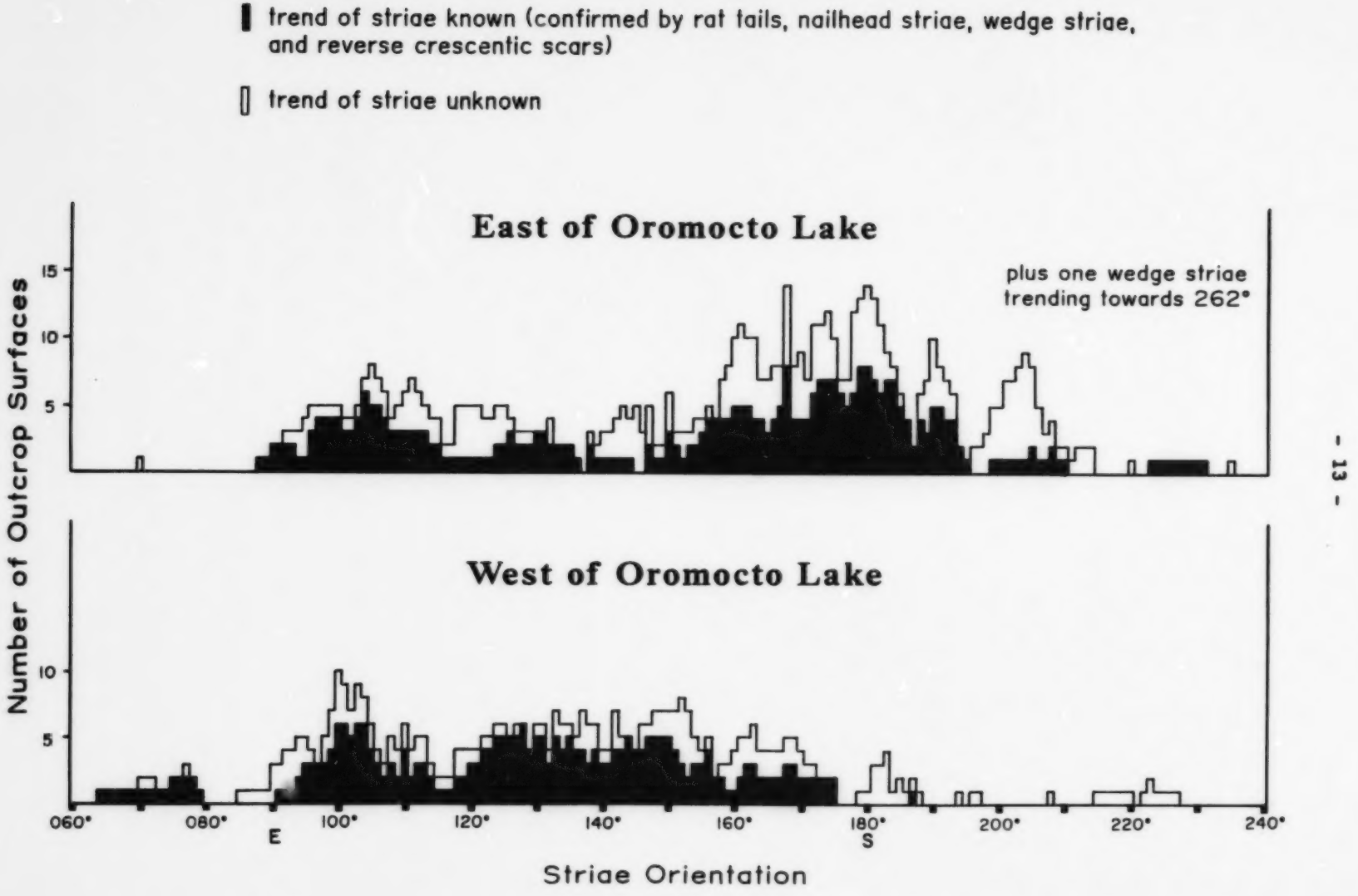


Figure 6. Histograms of striae trends in the Oromocto Lake area.

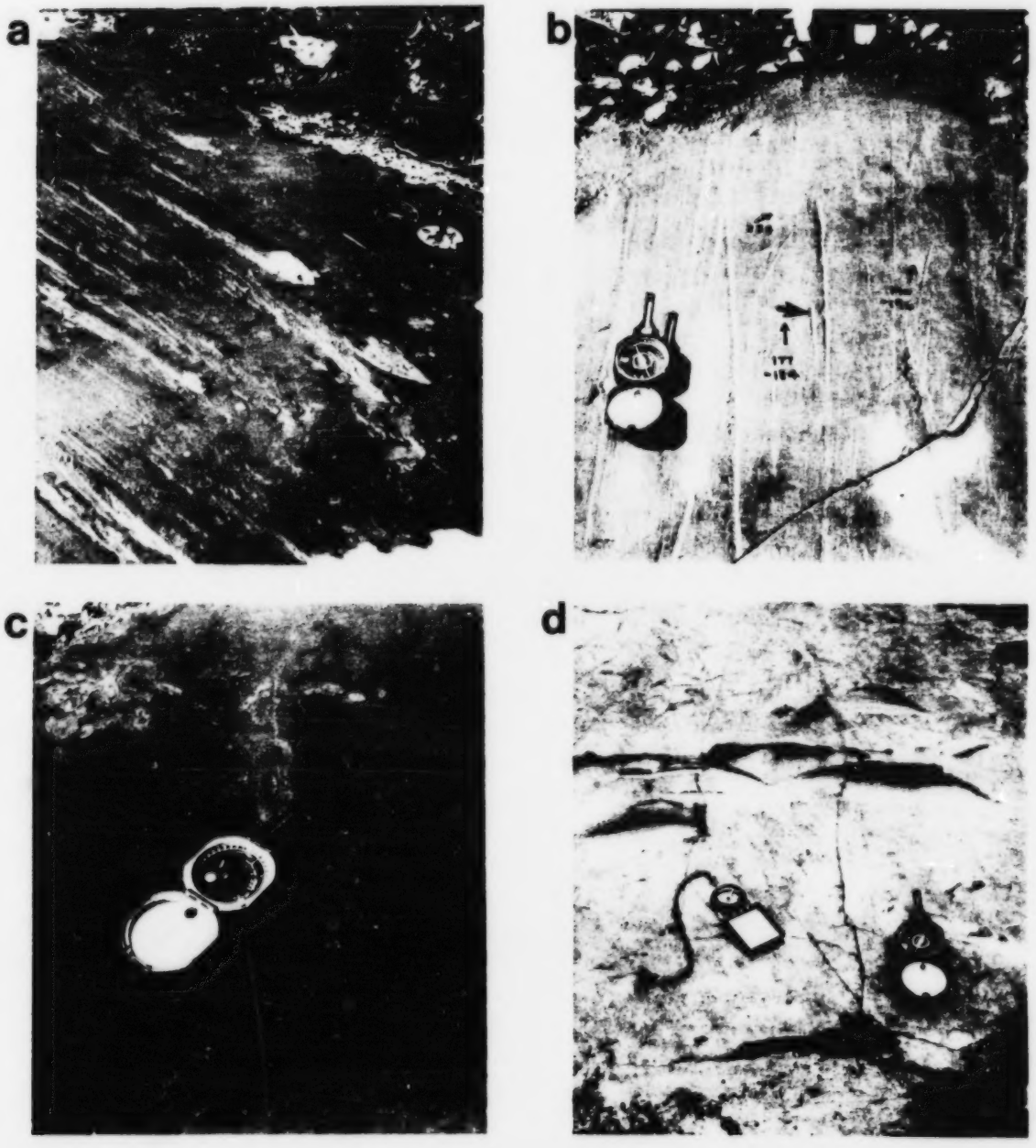


Figure 7. Indicators of ice-flow direction. (a) Rat-tails: linear ridges formed by non-erosion in the lee (down-ice) of resistant pebbles. (b) Wedge striae: elongated, triangle-shaped striae that widen, deepen, and then terminate abruptly down-ice. (c) Hailhead striae: similar to wedge striae, but T-shaped, with the head down-ice. (d) Crescentic scars: scars left by the removal of fragments of rock by glacial erosion - the scars may be convex down-ice (crescentic scars) or concave down-ice (reverse crescentic scars, as illustrated), and are differentiated by the presence of the steep, plucked face on the down-ice side of the scar.

TABLE II. CROSS-CUTTING STRIAE RELATIONSHIPS

West of Oromocto Lake, NTS 21 G/11

Site	UTM Coordinates	Chronology	Relationship
88-14	65565 506395	166° -> 140°	140° striae striate west flanks of 166° rat-tails
	64120 505760	149° -> 163°	163° striae cut south sides of 149° grooves
		149° -> 104°	149° striae and grooves occur only in positions sheltered from the 104° flow
88-27	65585 504420	167° -> 106° 146° -> 106°	106° striae striate west flanks of of 167° and 146° rat-tails
	65525 504395	135° -> 104°	104° striae striate west flanks of 135° rat-tails

East of Oromocto Lake, NTS 21 G/10

Site	UTM Coordinates	Chronology	Relationship
88-20	66585 504900	163° -> 140°	140° striae striate west flanks of 163° rat-tails
88-24	67140 504080	147° -> 163°	163° striae cut south sides of 147° grooves
	66185 504685	166° -> 104° 146° -> 104°	166° and 146° striae occur only on an east-facing slope bevelled by the 104° flow
88-25	66425 504795	138° -> 108°	138° striae appear to occur only in positions sheltered from the 108° flow

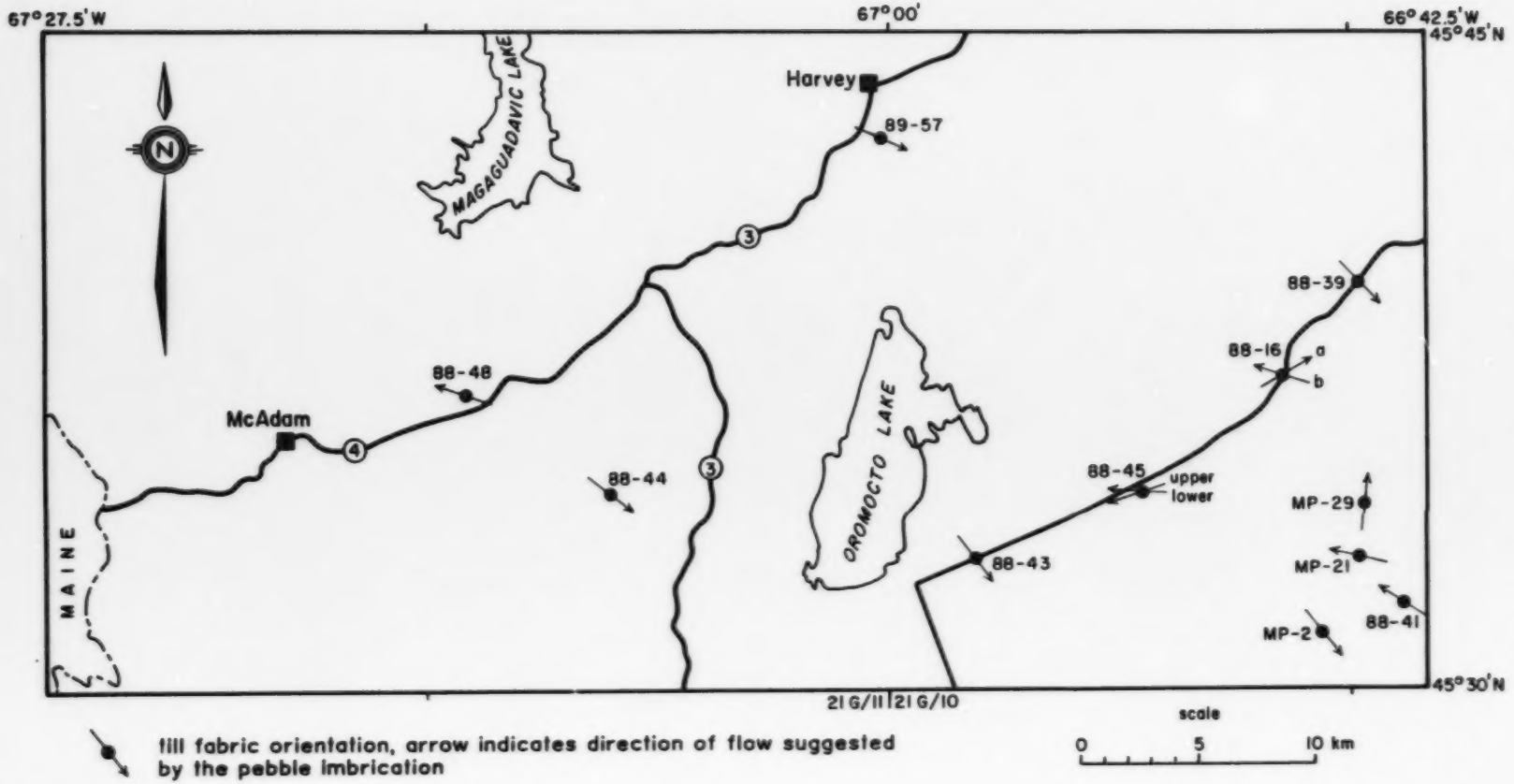


Figure 8. Till fabric orientations, Oromocto Lake area.

till can suggest the direction of ice flow (they are presumed to plunge in the up-ice direction) (Rappol 1986).

Till fabrics were measured at fifteen sites in the Oromocto Lake area (Figure 8). The data from each site were processed by an eigenvalue method (Mark 1973; Woodcock and Naylor 1983), using a computer programme supplied by R. Burns of the Terrain Sciences Division of the Geological Survey of Canada. The results for the twelve sites that exhibited non-randomness at the 99% confidence level are tabulated in Table III, and plotted on Figure 8.

Correlation Between Till Fabric and Striae Data If the major ice-flow directions, as recorded by the dominant striae peaks, are responsible for till deposition, then the till fabrics to the west of Oromocto Lake should have a northwest-southeast orientation while those to the east should have a north-south orientation. However, this is not the case. Only one of the three fabrics to the west of the lake has a southeastward orientation; only one of the ten fabrics to the east has a southward orientation. In addition, most of the fabrics are not perpendicular to the major striae trends, and thus are not likely transverse fabrics related to them.

Each till fabric does, however, closely parallel one of the many peak striae directions that are known from the area. For example, the till fabric at Site 88-39

TABLE III. TILL FABRICS FROM THE OROMOCTO LAKE AREA

Site	No. of Clasts	Trend of Principal Eigenvector	Plunge of Principal Eigenvector	SV§	Probable Ice-flow Direction
88-16a*	30	240°	39°	.620	060°
88-16b*	30	108°	13°	.521	288°
88-39	50	315°	20°	.519	135°
88-41	50	121°	24°	.589	301°
88-43	50	322°	35°	.696	142°
88-44	50	308°	21°	.723	128°
88-45Lower	25	092°	4°	.588	272°
88-45Upper	25	071°	23°	.599	251°
88-48	50	108°	5°	.589	288°
89-57	25	294°	20°	.798	114°
MP-2	25	321°	16°	.738	141°
MP-21	25	103°	3°	.480	283°
MP-29	25	186°	10°	.571	006°

§ Significance value
* Sites 88-16a and 16b are separated by a distance of 35 m.
All fabrics are non-random at the 99% confidence level.

suggests ice-flow toward 135°. At a site about 200 m to the southwest, a sandstone surface exposes prominent southward-trending striae and rat-tails cross-cut locally by a minor set of striae trending toward 129°. Unfortunately, the till fabric trend varies widely from site to site (Figure 8). This holds true even for tills of the same obvious physical characteristics. For example, the tills at sites 88-16a, 88-16b, 88-39, 88-41, and 88-45 (upper and lower) are all stony silty clays or sandy silts of the same reddish-brown colour (5YR 4/3), but with distinctly different clast orientations. In addition, the imbrication of the clasts in the tills, as indicated by the plunge of the principal eigenvector, suggests that some of the tills may have been deposited by ice flowing in the opposite sense to the trend indicated by the striae. For example, the till fabric at Site MP-29 suggests ice flow toward the north, rather than the southward flow indicated by erosional features in the area.

The lack of correspondence between the till fabrics and the major erosional ice-flow trends raises several questions. Are the erosional events, as recorded by the major striae sets, distinctly different and earlier events than those

Figure 9a. The exposure at Site 88-16b in September, 1988. The till fabric and pebble lithology sample were obtained from the lower 0.2 m adjacent to the stadia rod. The pen (1) marks the trend of the 183° striae set; the compass (2) marks the trend of the 201° set.

responsible for till transport and deposition? Are the minor striae sets correlated in any way with the till fabric trends? Are the till fabric trends consistently parallel to, transverse to, or at some other angle to the actual till transport direction? In an attempt to answer these questions, one site was examined in considerable detail.

Site 88-16b: Anatomy of a Site

Site 88-16b comprises a ditch exposure on the east side of the Peltoma Settlement Road (Figure 8), approximately 7 km to the southwest of Upper Tracy. The section at the site is 0.9 m high, and exposes 0.4 m of postglacial soil developed in the upper part of a very dense, reddish brown (5YR 4/3) stony silty clay till that, in turn, directly overlies sandstone bedrock.

The site was first examined in September of 1988. At that time the section was cleaned off and the fabric was measured in the lower 0.2 m of the till (by recording the orientation and plunge of 30 elongate pebbles with an a/b axis ratio of 1.5 or greater). Major striae and rat-tails trending toward 183°, cross-cut by finer and later striae trending toward 201°, were observed on the bedrock surface adjacent to the section (Figure 9a).

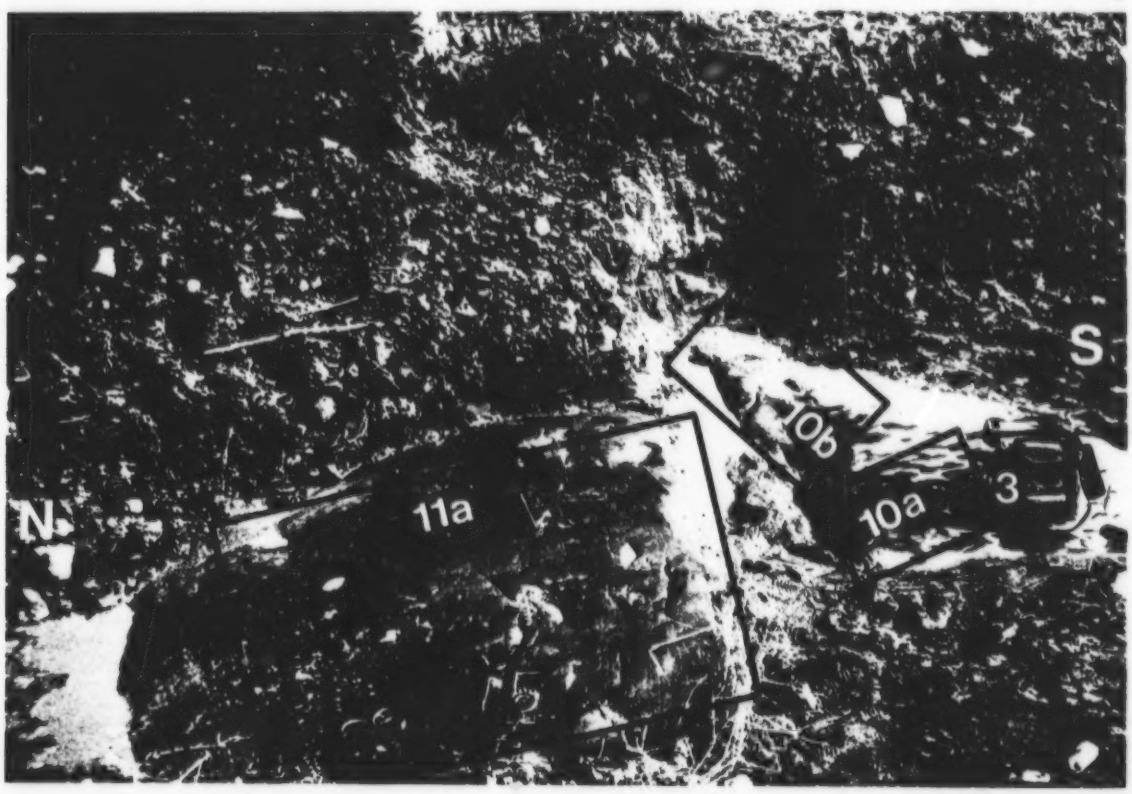


Figure 9b. The enlarged exposure at Site 88-16b in September, 1989. The camera bag (3) sits on the same outcrop surface as the one with the pen and compass in Figure 9a. Figures 10 and 11 illustrate the bedrock surface in greater detail.

The site was revisited during the summer of 1989 to obtain a sample of till pebbles for lithological analysis. At that time, it was noted that runoff in the ditch had enlarged the bedrock exposure, and exposed a small patch of striae trending toward 122°. Consequently, the site was revisited in September of 1989 and more of the bedrock surface was cleaned off and washed down.

The newly exposed bedrock surface consisted of two parts separated by a till-filled, roughly east-west oriented trough about 0.3 m wide (Figure 9b). The southern part of the outcrop (Figures 10a and 10b) is dominated by striae (including wedge and nailhead striae) trending toward 180° (±5°), accompanied by rat-tails. A minor set of striae (including a wedge striae) trending at 170° (±2°) is confined primarily to the western part of this surface (Figure 10a); another minor set trending toward 188 to 193° (avg. 191°) occurs as a few striae scattered across the surface and a small cluster of rat-tails (Figure 10b); a third minor set trending toward 199 to 204° (avg. 201°) locally striate the eastern flanks of some of the 180° rat-tails. In addition, a single large nailhead striae trending toward 153° was observed

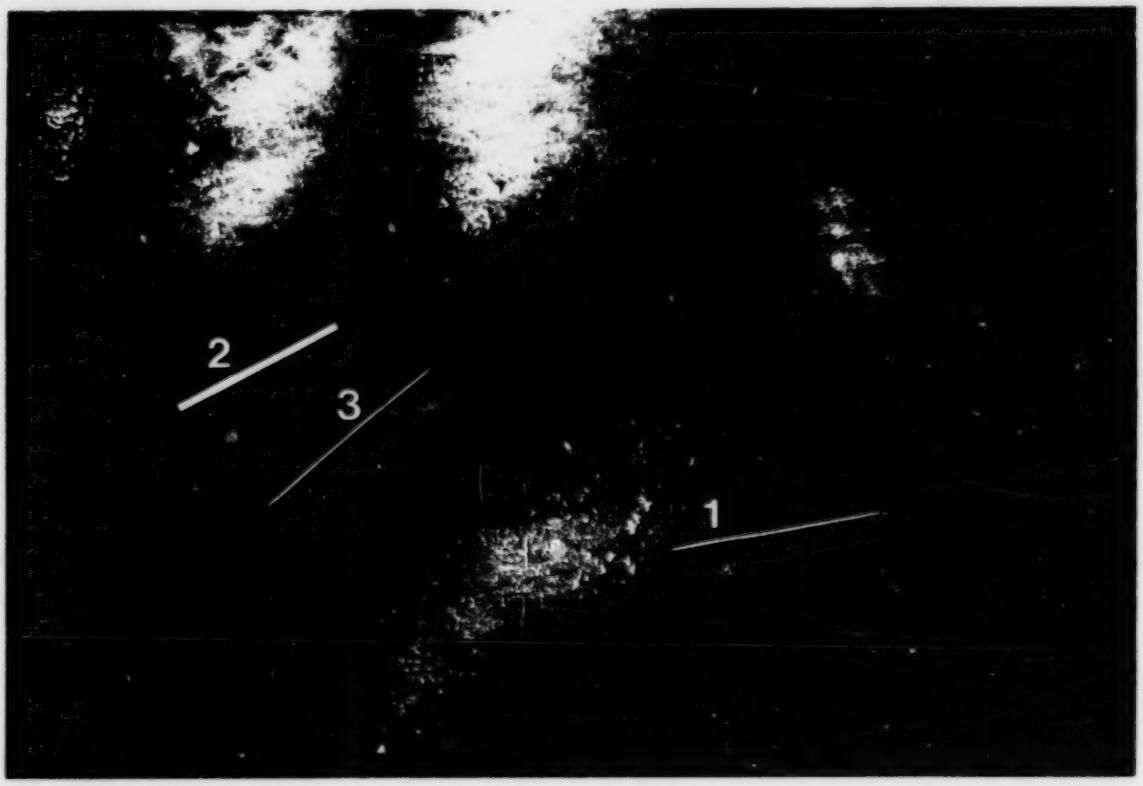


Figure 10a. Close-up of the western part of the southern outcrop surface at Site 88-16b (in the vicinity of the camera bag in Figure 9b). The 180° flow direction, with rat-tails, is dominant (parallel to the needle, 1). The straw (2) parallels the minor striae set trending toward 170°; the second needle (3) parallels the single wedge striae trending toward 153°.

(Figure 10a).

The northern part of the outcrop surface is also dominated by southward-trending striae (176 to 181°, with an average trend of 179°) accompanied by rat-tails, and also some rather worn reverse crescentic scars (Figure 11a). On the east side of this surface a few striae with an indefinite orientation of 199° (±1°) and a couple near the centre with an orientation (similarly indefinite) of 168° replicated two of the minor sets observed on the southern part of the outcrop. Also, five additional striae sets were found on this surface. On the western third of the surface, the set trending toward 122° (±4°), including rat-tails and wedge striae, is locally dominant. Striae of this set clearly cross-cut, and thus postdate, rat-tails of the 179° set (Figure 11b). The remaining sets are confined to the central surface of the outcrop (a low ridge). These include a minor set of striae (including wedge and nailhead striae) trending toward 096 to 104° (avg. 101°); a few striae including a wedge, with a trend toward 110° (±1°); a couple, including a wedge striae, with a trend toward 093 to 094°; and a single striae with an indefinite orientation of 161°.

In total, ten separate sets of

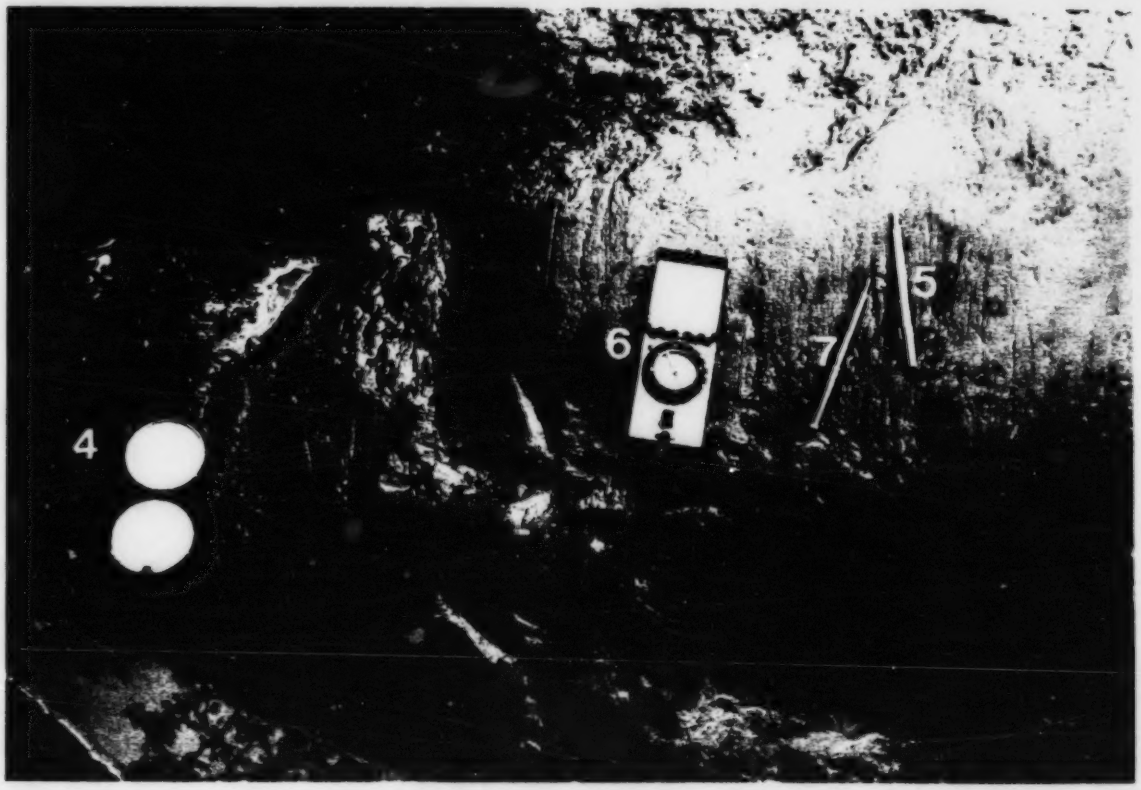


Figure 10b. The eastern part of the southern outcrop surface at Site 88-16b, immediately adjacent to the till section. The Brunton compass (4) and the pen (5) parallel 180° rat-tails; the Silva compass (6) parallels 191° rat-tails; and the felt-tip pen (7) parallels the 201° striae set (which striates the west flank of the rat-tail between the two pens).

striae have been identified on this outcrop (though the 093 to 094° set could possibly be part of the 096 to 104° set). The average trend of each set lies within a few degrees of a peak in the striae histogram for the area (Figure 6). The only definite chronological relationships observed are between the 180° set and the later 201° and 122° sets. However, the local occurrence of the 110°, 101° and 094° sets only on a high point of the bedrock surface, suggests that they are the latest events. If this is true, it would be expected that the till fabric would parallel one of these directions. This is, in fact, the case.

The principal eigenvector for the till fabric at this site has an orientation of 108°/288°. However, the plunge suggests that ice-flow was toward 288° (west-northwestward), an ice-flow direction that has never been reported from the area (see Seaman 1989a). In addition, if the fabric is transverse, it could indicate ice flow toward 198° (or the reverse), which correlates with one of the minor striae sets on the southern part of the outcrop surface. The significance value for the principal eigenvector is low, only 0.521. This suggests that there is considerable dispersion about the trend of this eigenvector, irrespective of

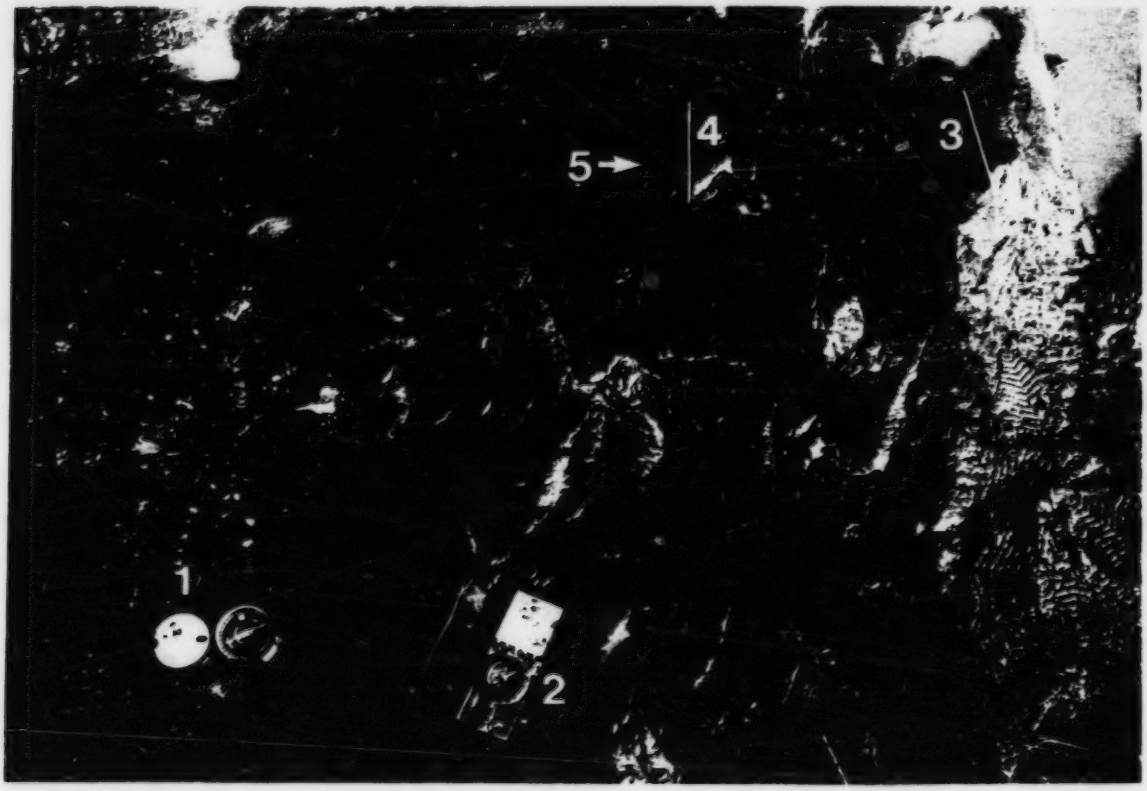


Figure 11a. The western part of the northern outcrop surface at Site 88-16b. Striae with rat-tails and reverse crescentic scars, trending toward 179° (parallel to the Brunton compass, 1), are cross-cut by striae and rat-tails trending toward 122° (parallel to Silva compass, 2). The needles (3 and 4) parallel striae trending toward 093° (3) and 101° (4). A large wedge striae (5) trending toward 110° lies a few centimetres from the left needle (4).

whether it is parallel or transverse to the ice-flow direction. A mirror-image plot of the till fabric (Figure 12) illustrates this dispersion. This till fabric plot clearly consists of two major peaks, one parallel to the principal eigenvector, and five minor peaks. Each of these peaks parallels a striae trend that has been observed in the area. This could be taken to indicate that the till fabric is polygenetic. However, given that the known striae trends occur at approximately 10° intervals over a sector of 180° (c.f. Figure 6), it would be impossible for these till fabric peaks not to parallel the striae trends. Obviously, given the low significance value of the principal eigenvector and the polymodal nature of the mirror-image plot, till fabric analysis cannot provide a reliable solution to the problem of determining the direction of ice-flow responsible for till deposition at this site.

All of the other till fabrics measured in the area are similarly polymodal, with from 3 to 9 peaks and generally low significance values for their principal eigenvectors (Table III), and thus, are suspect also. There are two probable reasons for this polymodality. First, the clasts may have been too short to align properly with the direction of ice-flow. Andrews (1971) noted that the commonly accepted minimum a/b axis ratio is 2:1, though lower ratios can be used if necessary. In order to keep the till fabric

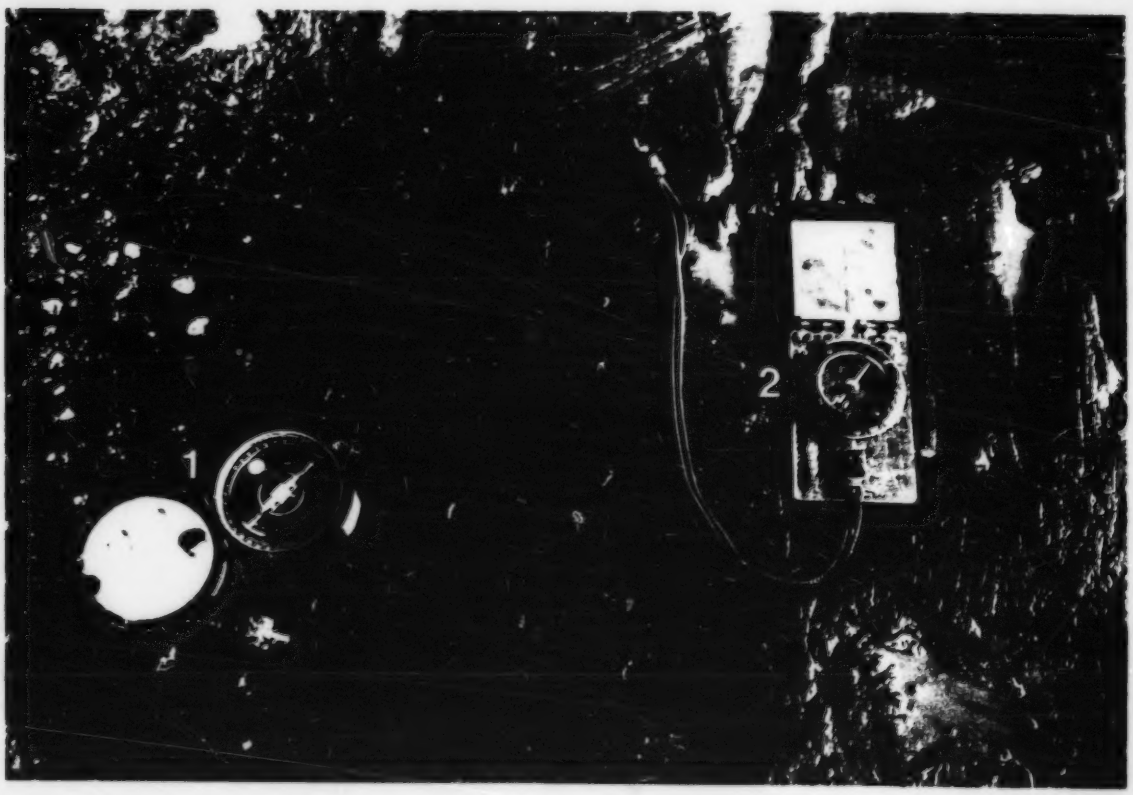
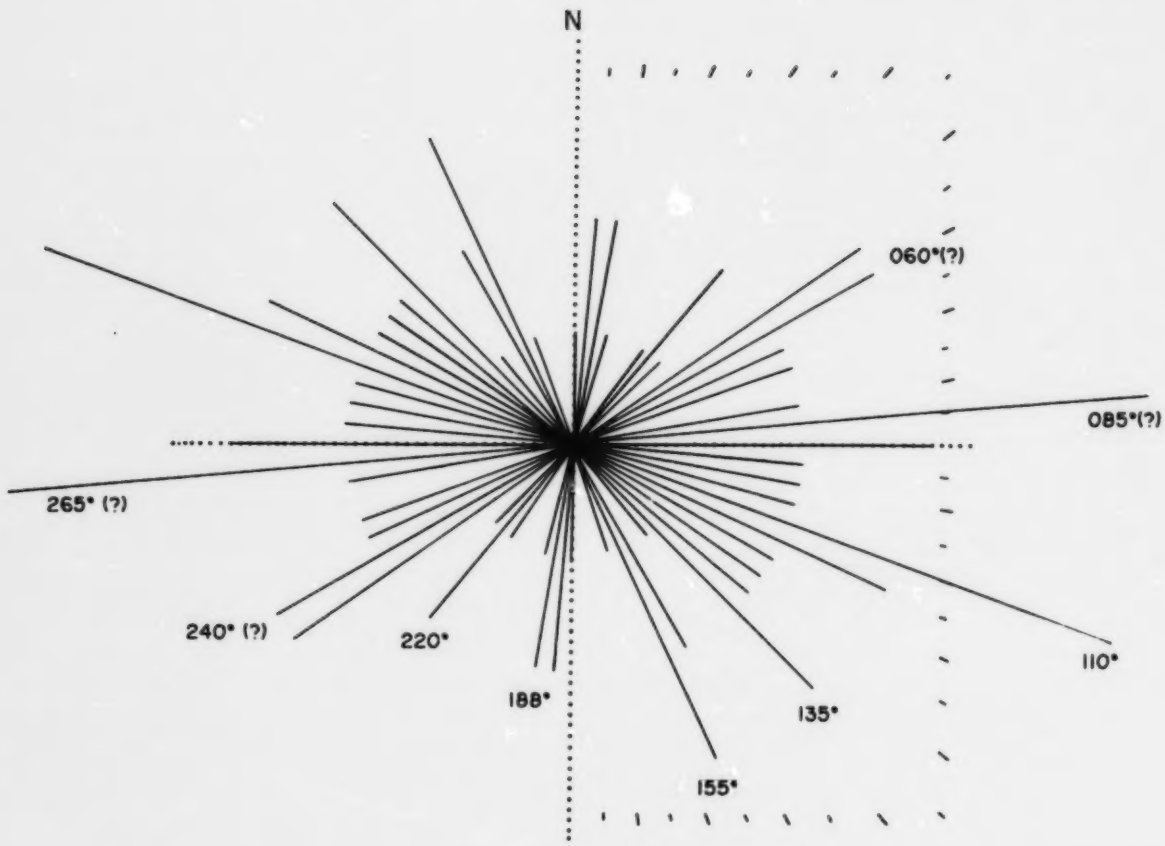


Figure 11b. Close-up of the outcrop surface between the two compasses in Figure 11a showing the 122° striae set cross-cutting rat-tails of the 179° set.

TILL FABRIC

Site : 88-16b
N.T.S. : 21 G/10
U.T.M. : 728 542



1 pebble = 2cm
n = 30

Notes: mirror image plot, double plotted around the "0" (i.e., 090 represents 085-094) and around the "5" (i.e., 095 represents 090-099)

Figure 12. Mirror-image till fabric diagram for Site 88-16b.

measurement time to a reasonable 2 to 3 hours per site, it was necessary to use a minimum a/b axis ratio of 1.4:1 in this study. At most sites only about 30% of the clasts equalled or exceeded a ratio of 2:1; the average of all clasts was usually 1.8 or 1.9:1. Second, about half of the clasts at each site are prolate or roller shaped. Such clasts roll more easily than other shapes (Blatt et al. 1972), and would thus tend to be aligned transverse to ice-flow direction. Poorly elongated clasts of this shape would tend to be more unstable in transport (i.e., they would wobble), hence aiding in the generation of a dispersed fabric. As a consequence, it appears that till fabric analysis is unsuited to determining ice-flow direction in this part of south-western New Brunswick.

Since neither the striae trends nor the till fabric analysis can provide a unique solution to the direction of till transport at site 88-16b, the only alternative is to examine the components of the till itself. For this purpose, 50 pebbles with a b-axis dimension of between 2 cm and about 10 cm were collected and examined. Thirty of the pebbles were relatively soft, medium- to coarse-grained, grey to brown sandstones similar to the typical Pennsylvanian sandstones of the immediate area. Two pebbles were fine-grained redbed sediments, similar to the Mississipian beds that are exposed along the margins of the Pennsylvanian to the north, west and south (Potter et al. 1979). Another 15 of the pebbles were moderately hard, grey, fine-grained sandstones and siltstones, similar to the Silurian sedimentary rocks that are found farther to the north, west and south of the Carboniferous deposits (Potter et al. 1979). The remaining three pebbles were identified by four bedrock geologists as most probably derived from the part of the Saint George Batholith to the southeast of the site! Preliminary examination of pebble samples from some of the other nearby till fabric sites suggests that they too were derived from source areas to the south or southeast.

Thus, neither the striae trends nor the till fabric successfully predict the source area for the pebble component of the till at Site 88-16b. However, the few sites examined are not sufficient for one to state definitively that all drift units in the Oromocto Lake area were transported in a northerly direction. Certainly, palaeocurrent and pebble lithology data for the meltwater deposits to the west of the lake (Seaman 1982) show that these deposits were transported in a southerly direction. Therefore, further work is required to determine the extent of this previously unknown northerly ice flow indicated by the till pebble lithology at Site 88-16b and its correlation with other deposit types, and also to confirm that the finer fractions of the till (the typical sample medium used in mineral exploration programmes) also derive from the same source area. While the till pebbles were derived from the area to the southeast, the ice flow that transported them did not necessarily follow a straight-line trajectory; it could have been curved or have consisted of a number of doglegs. Such a trajectory could result in a different geochemical response than expected.

SUMMARY

From the above, it is obvious that the glacial events in the Oromocto Lake area consisted of ice flowing in almost every direction of the compass at different times. However, there does appear to be a

pattern to the sequence of events. A preliminary analysis of the erosional chronology in southwestern New Brunswick (Seaman 1989c) suggests that ice-flow trends changed stepwise from one to another as part of a general shift in flow pattern. A possible early southward-trending ice-flow event may have been followed by counter-clockwise shift in the ice-flow direction toward the southeast, followed by a shift in flow direction back toward the south and then to the southwest, in turn followed by another shift back toward southeastward flow and then eastward and east-northeastward flow. The till pebble lithology data, while limited, suggests that, for the area to the east of Oromocto Lake at least, the ice-flow trend continued to shift until it had swung around to flow northward or northwestward, in the opposite direction to many of the erosional indicators.

This sequence of events suggests that an ice centre or dome initially to the north of the Oromocto Lake area migrated westward, then eastward, and then westward again. It then either migrated southward or was replaced by a centre to the west of the area. Migration of the ice centre or development of new centres continued until the ice centre lay to the south or southeast of the area.

The reasons for this remarkably complex sequence of glacial events are as yet unknown. However, its significance to the mineral explorationist is immediately apparent. It is an obvious waste of time and money to search for a mineralized zone to the north of a till geochemical anomaly because of the dominance of south-trending striae in the area, if, in fact, the till was transported northward by an ice-flow event that left no obvious erosional evidence of its passage.

RECOMMENDATIONS REGARDING DRIFT PROSPECTING IN NEW BRUNSWICK

The variety of glacial ice-flow patterns illustrated on Plate 89-11 and the above discussion of ice-flow events in the Oromocto Lake area of southwestern New Brunswick emphasize the complexity of glacial events in the Province. The map clearly reveals that the direction of ice flow in most regions of New Brunswick was highly variable. The complete reversal in flow directions known previously from the southeastern, northeastern and northwestern corners of the Province, and now identified in the southwest as well, probably occurred throughout the Province (remember, little data is available for some areas, particularly in the centre of the Province). It should, therefore, be apparent that a successful mineral exploration strategy using drift prospecting should involve more than simply collecting samples of glacial debris and then searching for the bedrock source of geochemical anomalies up-ice along the trend of the major glacial erosional pattern.

Three important considerations should be kept in mind in conducting drift prospecting in New Brunswick (and possibly in other glaciated regions also). First, a drift unit may be derived from almost any direction. The variety of ice-flow directions known from the different corners of the Province render plausible any direction of glacial transport. Second, evidence of glacial ice-flow direction derived from small- or large-scale erosional features may be irrelevant in determining the direction of ice-flow responsible for transportation and deposition of the drift units. Pronk and Burton (1988) have shown that till transport direction in part of northern New Brunswick was parallel

to the major ice-flow direction in that area. However, the Oromocto Lake example shows that glacial debris can be transported and deposited without significant glacial erosion of the underlying bedrock, and in a sense totally opposite to that indicated by the ice-flow direction indicators. Therefore, each exploration area must be individually assessed to determine whether or not the drift transport direction is in accord with the glacial erosion pattern of the area. Finally, immediately adjacent drift units may not necessarily be derived from the same source direction. As noted above, some of the tills in the Oromocto Lake area were transported in a northerly direction, while the meltwater deposits in the area consist of material that was transported southward.

As a result of the above, the following two recommendations are made:

(1) The source area for a drift unit should be determined using direct evidence from the unit in question. At this point in time, only the lithologic characteristics of a till have the potential to serve as definitive indicators of its source area. This in turn requires a thorough knowledge of the regional bedrock geology so that accurate correlations can be made. The geochemical signature of the till may also prove useful as an indicator of source area if the regional bedrock geochemistry is also known.

(2) Each drift unit must be accurately identified and then treated as a separate sample population. It should be remembered that individual units may be derived from totally different source areas. For example, a basal till unit may be derived from one quadrant of the compass, while an adjacent ablation till unit may be derived from a different quadrant. Both units in such a situation would be natural samples of totally different lithologic sequences.

Following these recommendations will undoubtedly increase the time and expense involved in determining the potential source area for a promising drift anomaly. However, ignoring them could easily result in a viable orebody remaining hidden beneath the drift, while the total cost of the exploration programme is written off as a loss. On the plus side, the challenge may be simplified by the fact that most geologists have more experience in lithological identification than in glacial geology.

ACKNOWLEDGEMENTS

Capable field assistance was provided in both 1988 and 1989 by Christopher Bianchi. Till fabrics at sites MP-2, MP-21 and MP-29 were measured by him as part of an independent mapping project. The pebble sample from Site 88-16b was examined by my colleagues L.R Fyffe, W.W. Gardiner, M.J. McLeod and S.R. McCutcheon. L.R. Fyffe also examined the pebble samples from several other sites.

A first draft of this report was critically read by my colleague A.G. Pronk, and by Dr. B.E. Broster (University of New Brunswick), R.R. Stea (Nova Scotia Department of Mines and Energy), and Dr. W.B. Thompson (Maine Geological Survey). Their comments and suggestions helped to improve and focus this report. Barbara Carroll edited and formatted the text, and Gerrard Johnson drafted the figures.

NOTE: In the time since this report was written, two significant volumes on drift prospecting have been published. These are as follows:

DILABIO, R.N.W., and COKER, W.B. (editors). 1989. Drift prospecting. Geological Survey of Canada, Paper 89-20, 169 p.

KUJANSUU, R., and SAARNISTO, M. (editors). 1990. Glacial indicator tracing. A.A. Balkema, Rotterdam, 252 p.

These volumes are recommended references for all persons conducting geological exploration in glaciated terrains.

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APPENDIX A.

DATA SYNTHESIS, AND PREPARATION OF PLATE 89-11

DATA SYNTHESIS

The striae data for each NTS map area (summarized in Seaman 1989a) were separated into two groups, one for those striae of definite trend and another for those of indefinite trend. Striae of definite trend are those for which the direction of ice flow is known (e.g., definite flow toward the east, as opposed to toward the west), typically based on indicators such as rat-tails, wedge or nailhead striae, stoss-and-lee features, etc. [see Prest (1983) for illustrations, descriptions and discussions of such features]. Striae of indefinite trend are those for which the sense of the ice flow is unknown (e.g., flow either toward the east or toward the west). These indefinite-trending striae were synthesized using both of the possible trends.

Indicators of ice-flow direction are well known to modern Quaternary geologists. Consequently, definite striae trends documented as such in reports or on maps prepared by Quaternary geologists since 1950 (i.e., Quaternary geology maps, reports, theses and papers; and granular aggregate inventory maps) were accepted without question. However, because of some questions regarding the evidence used by Chalmers (1884, 1885, 1887, 1888, 1890, 1893, 1895, 1902) to determine ice-flow direction, his data was treated as indefinite, except for those sites for which he gave evidence to support his interpretation of the direction of ice flow. The striae trends plotted on bedrock maps were also treated with caution. The degree to which bedrock geologists are familiar with glacial geology is highly variable. On many bedrock maps, all of the striae are mapped as being of definite trend. However, it is unusual for a Quaternary geologist to unequivocally determine the direction of ice flow at every site within an area. Consequently, it was assumed that the definite trends plotted on such bedrock maps were actually assumed trends, based on general evidence from other areas or sources, and not site specific data. However, if a bedrock map had both definite and indefinite trends plotted (indicating that the geologist had some familiarity with differentiating the two), then the definite trends were assumed to be correct if they were consistent with data from other sources.

Each striae orientation measurement was assumed to lie at the centre of an arc of 11° (e.g., an orientation of 172° was assumed to represent the sector from 167° to 177°). There were three reasons for this. First, many geologists appear to round their orientation measurements to the nearest 5 or 10° (e.g., Gadd 1973). Second, for those cases where striae are presented simply as map symbols, the combination of initial plotting, drafting and printing, and the subsequent measurement of orientations from the drafted symbols was estimated to result in an error of up to ±5°. For example, in his report Caley (1936) gives an orientation of 150° for a striae site; however, the orientation measured from his map was 146°. Third, in the author's experience, one striae set can typically cover a range in the order of 5 to 10° (e.g., Table I).

The next step in the data synthesis was to compile the overlapping sectors of the definite striae trends and, separately, the indefinite striae trends for each NTS map area. The indefinite striae sectors were then compared with the definite sectors for the map sheet in question and also with those of the immediately adjacent map areas (up to 8). This comparison with the data of definite trend from the adjacent map areas was justified on the assumption that ice-flow events

that occurred in one map area probably occurred in the adjacent area also. Those indefinite sectors that overlapped such definite sectors were accorded "probable" status. However, in some cases, both possible trends, or neither possible trend, were present within the immediately adjacent map areas. In these cases, since neither trend could be identified as most probable, both trends were identified as "possible."

Needless to say, there were many cases of incomplete overlap between the definite and the indefinite sectors. One original indefinite sector of 11° can potentially break down into definite, probable and possible segments. For example, there could be a definite sector of 085-095° and a partially overlapping indefinite sector of 092-110° in one map area. In the immediately adjacent map areas, there could be a combined definite sector of 076-107°. The resulting sector segments would thus be as follows: definite, 085-095°; probable, 096-107°; and possible, 108-110° and the reverse, 288-290°. Since the reverse possible sector is less than 6° of arc in width, it is probably not significant; such small isolated sectors can probably be safely ignored.

The above procedure was followed for each 1:50 000 scale NTS map area. The resulting synthesized striae trend sectors for each map area are tabulated in Appendix B. "Definite" striae trend sectors are underscored; "probable" trend sectors are not highlighted; and "possible" trend sectors are enclosed in parentheses.

It should be emphasized here that this synthesis is not a final, true product. It is only as good and comprehensive as the original data, which for some map areas is very sparse. Future investigations will undoubtedly disclose additional sectors in some areas or upgrade existing sectors from possible to probable or definite, or from probable up to definite or down to possible. (For example, new data collected during 1989 would add new ranges to several areas). In addition, it should be noted that this synthesis is based on New Brunswick data only. Striae data from Nova Scotia (Finck and Stea 1984; Stea 1984; Stea et al. 1986; Stea and Grant 1982), Prince Edward Island (Prest 1973), Quebec (Lortie and Martineau 1987) and Maine (Thompson and Borns 1985) were examined briefly to ensure that there were no blatant contradictions with the New Brunswick data, but were not included in the compilation or the interpretation.

Presentation For presentation on the accompanying 1:500 000 scale map (Plate 89-11), the synthesized data (Appendix B) needed further simplification. Therefore, for plotting purposes, the definite and probable sectors were combined. In addition, if one possible trend seemed to be more likely than the reverse trend, based on overall regional trend patterns, the former was assumed to be correct and the latter was omitted from the map. Therefore, the map synthesis comprises two types of sectors: definite or probable, and assumed or possible.

The plotted information was further simplified by the incorporation of small sector segments into larger adjacent segments and by the bridging of small gaps between adjacent sectors. Appendix B is set up so that each line of information (a line of sector segments plus any indented lines beneath it) comprises one continuous sector block that may be all definite or probable, all assumed or possible, or a combination of the two.

Example The process involved in this method of data synthesis and presentation can be best illustrated by the use of a simple example. The data set for the Juniper (NTS 21 J/11) map area will be used for this purpose. The only striae data from this area is that of Chalmers (1902), who reported four striae orientations: 125°, 152°, 153°, and 185°. None of these are of definite trend. Therefore, the data set consists of six potential ice-flow trend sectors: 120-130° and the reverse, 300-310°; 147-158° and the reverse, 327-338°; and 180-190° and the reverse, 000-010°.

These six indefinite sectors were next compared to the definite sectors for the eight immediately adjacent map areas (i.e., NTS 21 J/5, J/6, J/7, J/10, J/12, J/13, J/14, and J/15). The indefinite sector 120-130° is overlapped or partly overlapped by definite sectors from map areas 21 J/12, J/14 and J/15. Similarly, the indefinite sector 180-190° corresponds to definite sectors for map areas 21 J/5, J/6 and J/14. Since no definite data for ice flow toward the reverse directions was available for the adjacent areas, these reverse trends were deleted from the data set, leaving the southeast and south trends as "probable." However, the situation is different for the remaining pair of sectors. The 147-158° sector has an overlap of 2° with a definite sector from map area 21 J/5. This results in a probable trend sector of 157-158° adjacent to a possible trend sector of 147-156°, plus a possible trend sector in the reverse direction, toward 327-336°. Examination of the probable and possible trend data for the adjacent map areas reveals that south-southeast ice flow is probable throughout the region, while north-northwest flow is possible in the region to the north and west. Consequently, there is no justification in assuming that one of these trends is more likely than the other; therefore, both are plotted as "possible" on the map. Since the 157-158° probable trend sector is too narrow to be plotted on the map, it is combined with the adjacent possible trend sector.

APPENDIX B

Glacial Ice-flow Directions in New Brunswick

Definite ranges - underscored, e.g., <u>091-136</u>

Probable ranges - not highlighted, e.g., 137-183

Possible ranges - in parentheses, e.g., (184-201)

GLACIAL ICE FLOW DIRECTIONS

11 L/4, Cape Tormentine

066-075, (076)
(119-138)
(154-162), 163-183, 184-207,
208-216, 217-232
285-295
(299-318), 319-337, (338-342)

21 B/10, Grand Manan Island

(063-080), (082-094), 095-102
114-146, (146-171), (175-195)
(243-260), (262-274)
(327-351), (355-015)

21 B/15, Campobello Island

095-146, 147-185

21 G/1, Musquash

075-085
095-105
110-115, 116 - 195, 196-205, 209-219

21 G/2, St. George

(065-069), 070-085, (086-094),
095-195, 195-204
(266-274)

21 G/3, St. Stephen

(065-069), 070-075
110-180
185-195

21 G/6, Rollingdam

065-075
085, (086-089), 090-095, 099-109,
110-125, 126-156, 157-177
(200-204), 205-210
221 - 231

21 G/7, McDougall Lake

059-069
097-124, 125-135, 136-141, 142-152,
153-167, 168-190, 191-200, 204-214

21 G/8, Saint John

(045-065)
073-083, 085-090, (091-094), 095-124,
125-135, 136-141, 142-179, 180-185,
186-206, 207-213, 214-224,
(225-245)

21 G/9, Hampstead

(055-056), 057-067, (068-070)
080-090
115-124, 125-170, 171-183, 185-195
210-220

21 G/10, Fredericton Junction

090-192, 193-204, 205-215

21 G/11, McAdam

059-069, (070-073), 074-084,
(086-089), 090-092, 093-116,
117-119, 120-188

21 G/12, Forest City

120-133, 134-144, 145-155

21 G/13, Fosterville

120-169

21 G/14, Canterbury

105-120, 124-127, 128-145, 146-148, 149-175, 176-186

21 G/15, Fredericton

(055-058), 059-065
092-137, 138-170, 171-190
197-198, (199), 200-207
215, (216-218), 219-225

21 G/16, Grand Lake

130-150, 151-154, 155-165, 166-169, 170-195, 195-204, 205-215

21 H/4, Cape Spencer

(045-060)
125-134, 135-209, 210-224, (225-240)

21 H/5, Loch Lomond

120-221

21 H/6, Salmon River

116-126
135-145, 147-176

21 H/10, Alma

(012-070), (075-080), 081-198, 109-173, (174-177), 178-260
(295-310)
(347-005)

21 H/11, Waterford

(051-070), (075)
110-114, (115-122), 123-185, 186-191, 192-202
(231-250), 251-254, (255)
(295-310)
(347-003)

21 H/12, Sussex

067, (068-077)
125-135
145-154, 155-191, 192-197
(248-257)

21 H/13, Codys

057-067
(105-106), 107-115
125-138, 139, 140-205, 206-215

21 H/14, Petitcodiac

(025-035), (040-044), 045-055
(080), 081-090
(130), 131-140, 142 -155, 156-168, (169-185), 186-190
(205-215), (220-230)
(347-005)

21 H/15, Hillsborough

012-049, (050-051), 052-070, (073-074), 075-235, (236-250), (253-260)
295-310
(332-342)
347-005

21 H/16, Amherst

(012-049), (052-053)
154-207, (208-216), 217-227,
(228-229), 230-231, (232-233)
(347-005)

21 I/1, Port Elgin

(012-048)
063-064, 065-075, 076-084, 085-095
(121-130), 131, 133-138, (139-143)
(148-162), 163-166, (167-169),
170-180, (181-184), 185-225,
(226-228)
(301-310)
(328-331), 332-342
(347-005)

21 I/2, Moncton

028-038
(043-055), 056-060
068-084
112-114, (115-130), 131-134
148-158, (159-162), 163-166, (167)
(223-235)
(295-310)
(332-342)

21 I/3, Salisbury

064-087, 088-095
107-117, (118-120)
(295-300)

21 I/4, Chipman

(005-015)
(050-056), 057-060
065-084, 085-095
155-157, 158-168, 172-175, 176-186,
(187-195)
(230-236)

21 I/5, Salmon River Road

(004-006), 007, (008), 009-019,
(020-024)
(044-051), 052-062
073-083, 084-094, 095-099, 102-125,
(126-131)
141-153
181-183, (184-186), (188-191),
(194-198), (200-204)
(224-234)
(306-311)

21 I/6, Harcourt

004-057
079-089
104-114
(142-145), 146-168, (169-171),
172-183, (184-186)

21 I/7, Buctouche

004, (005-043), 044-054, 055-056,
057-067, 068-073
094-115
(146-147), 148-151, (152-154)
(163-169), 170-171, 172-182,
(185-225)
(343-349)

21 I/10, Richibucto

nil

21 I/11, Rogersville

007-017
054-064
073-112
315-325

21 I/12, Blackville

004-048
063-113
126-132, (133-134), (136)
153, (154-174)
(334-354)

21 I/13, Newcastle

(355-356), 357-015, 017-037,
038-051, 053-056, 057-092, 093-133
(138-148)
(155-157), 158-163, (164-168)
(175-183)
(318-328)

21 I/14, Kouchibouguac

015-025
(052-053), 054-057, 058-068, 070-084,
085-095, 096-102
326-336

21 I/15, Pointe-Sapin

nil

21 J/1, Minto

(010-030)
(035), 036-038, (039-050)
150, 151-161, 162-165
177-187, 188-198, (199), 200-210
(215), 219-236

21 J/2, Burtts Corner

(013-033)
(041-051)
(065-075)
088-098, (099-104), 105-121,
(122-125), 126-139, 140-172,
173-182, 183-198, (199-213), 214
(221-231)
(245-255)

21 J/3, Millville

088-098
110, 111-121, (122), 123-125,
126-141, 142-144, 145-181, 182-200

21 J/4, Woodstock

(087), 088-098
110-120, (121-122), 123-200, 201,
202-212

21 J/5, Florenceville

144-154, 157-168, 169-170, 171-185,
186, 187-206,
207-212, (213-215)

21 J/6, Coldstream

159-172, 173-185, 186-194, 197-202,
(203-207)

21 J/7, Napadogan

089-098, (099-110), 111
130-158
165-186
(279-290)

21 J/8, Boiestown

013-033, 035-055
063-073
155-165

21 J/9, Doaktown

008-041
065-075, 076-083
(133-135), 136-143
(169-176)
(349-356), 357-359

21 J/10, Hayesville

020-022, 023-051, 052-109
126-136

21 J/11, Juniper

120-130
(147-156), 157-158
180-190
(327-336)

21 J/12, Perth-Andover
(formerly Andover)

043-053, (054-062)
089-105
116-136
160-197
(234-242)

21 J/13, Aroostook

(020-028)
(062-064), 065-075, (076), 077-083
101-110, (111-122)
(160-161), (164-166), 167-177,
178-185
(200-203), 204-214, 215
(291-302)
(340-341), 342-343, (344-346)

21 J/14, Plaster Rock

094-109, (111-123), 125-138
(146-156)
176-189
(291-303)
(326-336)

21 J/15, Tuadook Lake

076-094, 095-124, 125-126, 130-140

21 J/16, McKendrick Lake

047-132, 134-135, 136-146, (147-149)
(322-329)

21 M/2, Connors

(105-112), (117-125)
(134-145)
283-293, 294-296, (297), 298-308
(314-325)
(335-339), 340-345
(355-356), (358), 359-005

21 M/6, Estcourt

(175-185)
(355-005)

21 M/7, Lac Baker

(105-112), (117-148)
(168-176), 177, (178)
270-283, (285-290), 291-309,
(310-312), 313-330, 331-334,
(335-339), 340, 343-347, (348-356),
(358), 359, 001-008, (009-011)

21 M/8, Edmundston

(096-101), 102-112, (113-116),
117-127, (128), 129-148
168-178
234-244
274-284, (285), 286-334, 335-339,
340-356, 358 -008

21 H/9, Grandmaison

065-070, (071-075)
(080-089), 090-100, (101-104), 105,
(106-124), 125-135, (136-142)
204-214
260-281, (282-284), 286-296,
(296-322)
(330-332), 333-334, (335), 336-340,
342-352

21 H/16, Wild Goose Lake

nil

21 O/1, Big Bald Mountain

030-032, 033-044, 045
059-118, (119-120), 121-148,
149-152, 153-163
173-183
(286-302)

21 O/2, Serpentine Lake

022-028, (029-032)
080-134

21 O/3, Riley Brook

018-028
(041-045), (048-058), (060-064),
065-075, 077-137, 138, (139),
(143-144), 145-161, (164-166),
167-170
185-189, (190-192), 193-197,
(198-208), 209-220, (221-225),
(228-238), (240-244)
(291-306)
320-321, (323-333), (335-341),
342-343, (344-346)

21 O/4, Grand Falls
(formerly Saint Andre)

(018-028)
(041-050), (053)
075-087, 088-117, (118-121),
122-132, (136-146), (150-160)
(167-187)
(190-192), 193-220, (221-230),
(233), 234-243
(274-281)
(287-290), 291-306, (307-310)
(316-319), 320-343, 345-346,
(347-356), (358-007)

21 O/5, Grand River

nil

21 O/6, Sisson Branch Reservoir

(018-028), (032-035)
069-085
110, (111-120), 121-131
150-160
195-197, (198-208), 209-211,
(212-215)
(291-300)
355-005

21 O/7, Nepisiguit Lakes

037-047
054-068
092-099, 100-118, 119-141, 143-153
(175-183)
(355-003), 004-005

21 O/8, California Lake

049-130
(254-271)
(297-302)

21 O/9, Tetagouche Lakes

(007-022), 025-120
129-151
(187-202)
(254-271)
(278-292)
344-000

21 O/10, Upsalquitch Forks

032-116
323-333
346-012

21 O/11, Kedgwick

035-045

21 O/12, Gounamitz River

080-136
265-277
(289-300)
315-325
336-346
(354-356), (358), 359-004

21 O/13, States Brook

060-070
087-127
142-152
317-321, (322-325)

21 O/14, Menneval

058-068

21 O/15, Atholville
(formerly Campbellton)

005, 006-016
025-108, 109-117
(158-163), (166-168)
(338-343), 344-345, (346-348)

21 O/16, Charlo

(347-006), 007-096, 097, (098-108)
116-126, 127-156, 157-163,
(164-165), 166-176, (177-234)
(254-271)
(278-288)

21 P/2, Point Escuminac

nil

21 P/3, Chatham

063-073, 074-087
(107-117)
130-140
(287-297)

21 P/4, Sevogle

350-005, 009-010, 011-045, (046),
047-056, 057 -085, 088-098
125-133, (134-135)
(140-157), 158-160
(320-321), 322-337

21 P/5, Nepisiguit Falls

008-045, 046-050, 051-117, (118-122)
132-152, (153-157), 158-163,
(164-167)
(254-271)
286-302
(329-337)

21 P/6, Tabusintac River

012-022
030-040
(082-090), 091-101
127-133, (134-137)
(262-271)
314-333

21 P/7, Wishart Point

nil

21 P/10, Tracadie

nil

21 P/11, Burnsville

nil

21 P/12, Bathurst

357-007, (008-023), 024-102,
(103-108)
118-133
155-173
(187-234)
254-271
(278-288)

21 P/13, Pointe Verte

(011-026), 027-234
(254-271)
278-288
(352), 353 003

21 P/14, Grand-Anse

069-073, (074-079)
(254-259)

21 P/15, Caraquet

nil

22 B/1, Escuminac

055-099, (100-102)
168-178

22 B/2, Oak Bay

080-092
098-108

MAPS
NOT
FILMED

CARTES
OMISES